THERMAL BEHAVIOUR OF SUNRISE, A BALLOON-BORNE SOLAR TELESCOPE

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ABSTRACT

Sunrise is a solar telescope, successfully flown in June 2009 with a long duration balloon from the Swedish Space Corporation Esrange launch site. The design of the thermal control of SUNRISE was quite critical because of the sensitivity to temperature of the opto-mechanical devices and the electronics. These problems got more complicated due the size and high power dissipation of the system. A detailed thermal mathematical model of SUNRISE was set up to predict temperatures. In this communication the thermal behaviour of SUNRISE during flight is presented. Flight temperatures of some devices are presented and analysed. The measured data have been compared with the predictions given by the thermal mathematical models. The main discrepancies between flight data and the temperatures predicted by the models have been identified. This allows thermal engineers to improve the knowledge of the thermal behaviour of the system for future missions.

1. INTRODUCTION

Sunrise is an international scientific project led by the Max Planck Institut für Sonnensystemforschung (MPS) with the participation of other european and american institutes, such as Kiepenheuer-Institut für Sonnenphysik (KIS), High Altitude Observatory (HAO-NCAR), Instituto de Astrofísica de Canarias (IAC), Instituto de Astrofísica de Andalucía (IAA-CSIC), Instituto de Técnica Aeroespacial (INTA), Instituto de Microgravedad "Ignacio Da Riva" (IDR/UPM) and Grupo de Astronomía y Ciencias del Espacio (GACE).

The 1-m solar telescope Sunrise (see Fig. 1) was successfully launched on 8th June 2009 at 6:27 UT (Universal Time) from the launch site at Esrange Space Center (near Kiruna/Sweden), and reached an initial float altitude of 37.2 km after an ascent of about three hours. After practically six days of flight at a floating altitude between 34 and 37 km, Sunrise landed on Somerset Island, Northern Canada, at 23:44 UT.

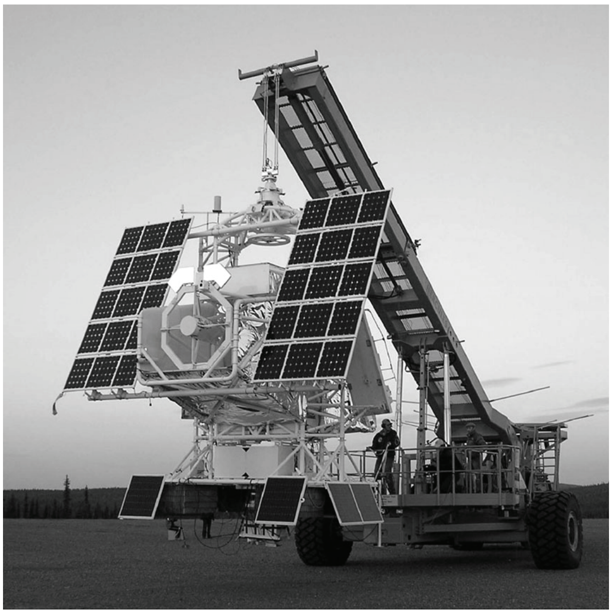

Figure 1. Overview of the Sunrise observatory in full flight configuration

The main scientific goal of Sunrise is to have a better understanding of the structure and dynamics of the magnetic field in the solar atmosphere. For more information, [1,2] can be referred.

The most demanding element from thermal point of view is the Post-focus Instrumentation Platform (PFI). The PFI package consists of a rigid support structure and four instrument modules with their proximity electronics. Two of the four modules previously mentioned are service units: Image Stabilization and Light Distribution (ISLiD) [3] and Correlation tracking and Wavefront Sensing (CWS). The other two modules are scientific instrumentation: Sunrise Filter Imager (SuFI) [3] and the Imaging Magnetograph Experiment (IMaX) [1]. The geometrical arrangement of these elements is depicted in Fig. 2.

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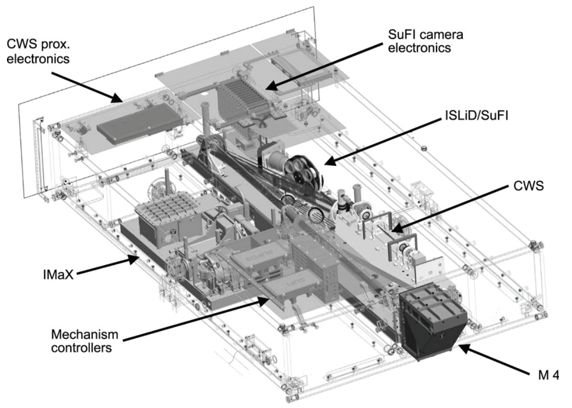

Figure 2. Semi-transparent view of the Sunrise PFI

2. PFI THERMAL DESIGN

The PFI structure is a honeycomb frame (CFRP (Carbon Fiber-Reinforced Plastic) skins 1.25 mm. thick, aluminum cell core 30 mm. thick), and there are three compartments for the scientific instruments (a detailed description of PFI architecture can be found in [2]). The thermal design of the Post-Focus Instrumentation is focused on temperature stability [5], in order to ensure the alignment of non-CFRP-based instruments (as IMaX) and to minimize changes of the polarization properties of the optics. Following this criteria, the overall temperature level has to be kept within a temperature range of 20 ± 10ºC. This a strong thermal constraint, due to many reasons, such as the great size of PFI module (2 m x1 m) and considerable power dissipation of the different electronic devices placed inside the PFI structure.

3. FLIGHT DATA

Sunrise was equipped with 256 temperature sensors; most of them reading temperatures every 3 seconds. In order to check if the PFI temperatures were in the desired range, sensor recordings have been plotted. In this work a few of them are shown as example. The different locations of the plotted temperature sensors can be found in Figs. 3, 4, 5 and 6.

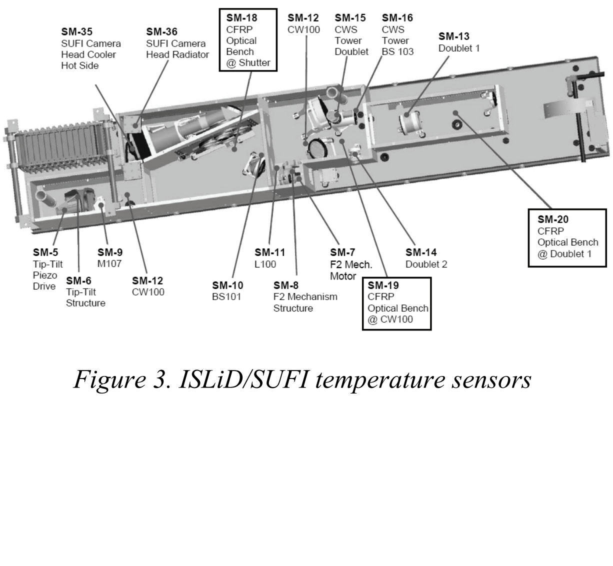

Figure 3. ISLiD/SUFI temperature sensors

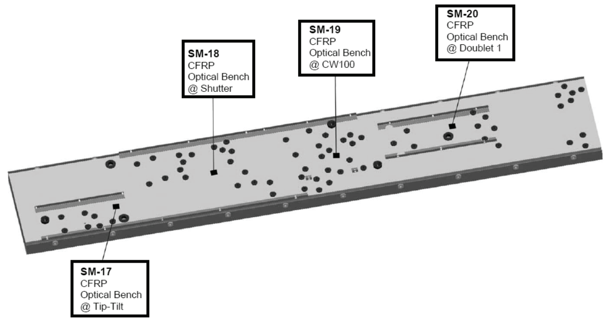

Figure 4. ISLiD CFRP optical bench temperature sensors

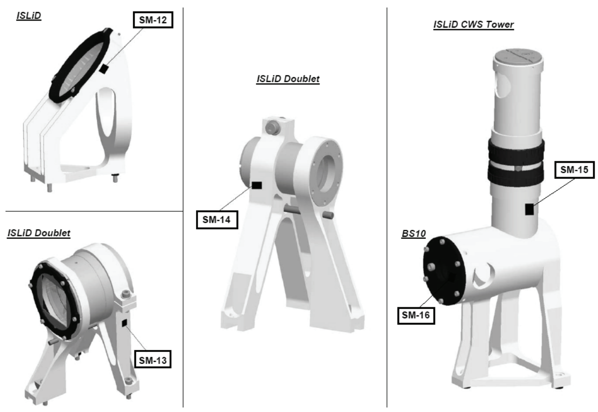

Figure 5. ISLiD Optics internal temperature sensors

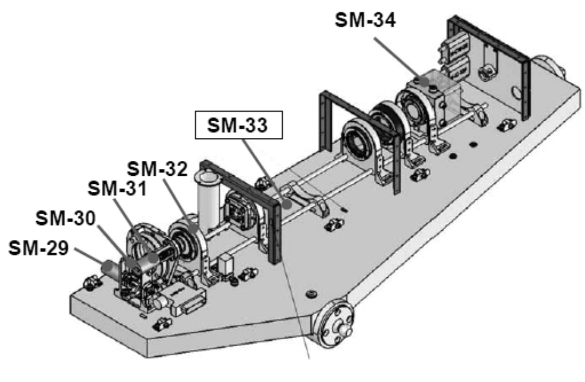

Figure 6. CWS Optical bench temperature sensors

The plotted temperature sensors are those inside text boxes in the figures. In Figs. 7 and 8, temperatures measured by the sensors indicated previously have been represented versus time (universal time, day of June, *x*-axis). The ascent phase (first part of the day 8th of June, see [4]) has been overlooked. This phase was already analysed in detail [4,5]. Result of this study and the measurements carried out during the test flight showed the necessity of using a wind shield to prevent the system from an excessive cooling during the ascent. The

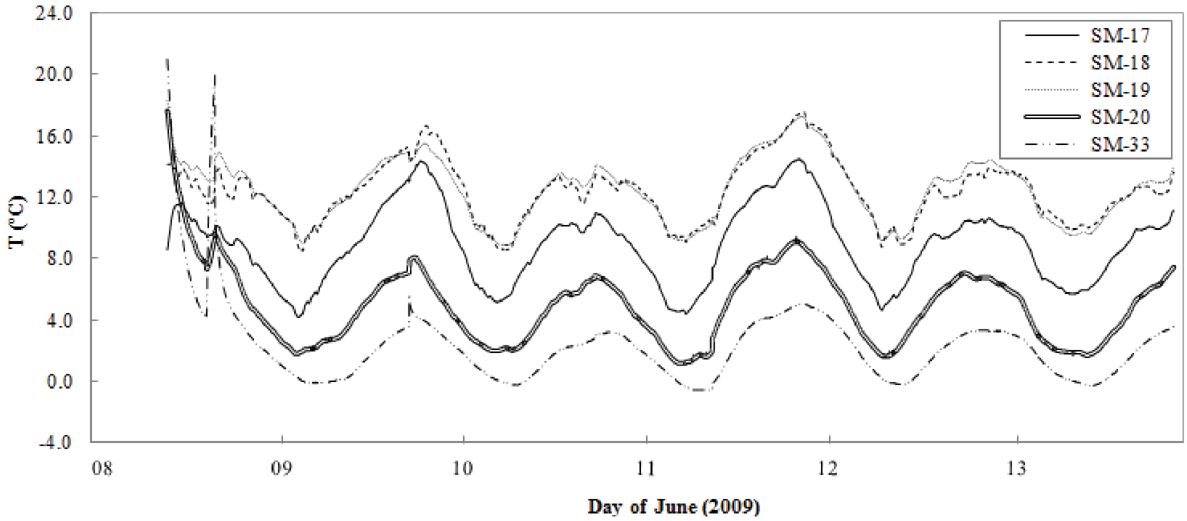

Figure 7. ISLiD/SUFI and CWS Optical Benches SM temperature sensors

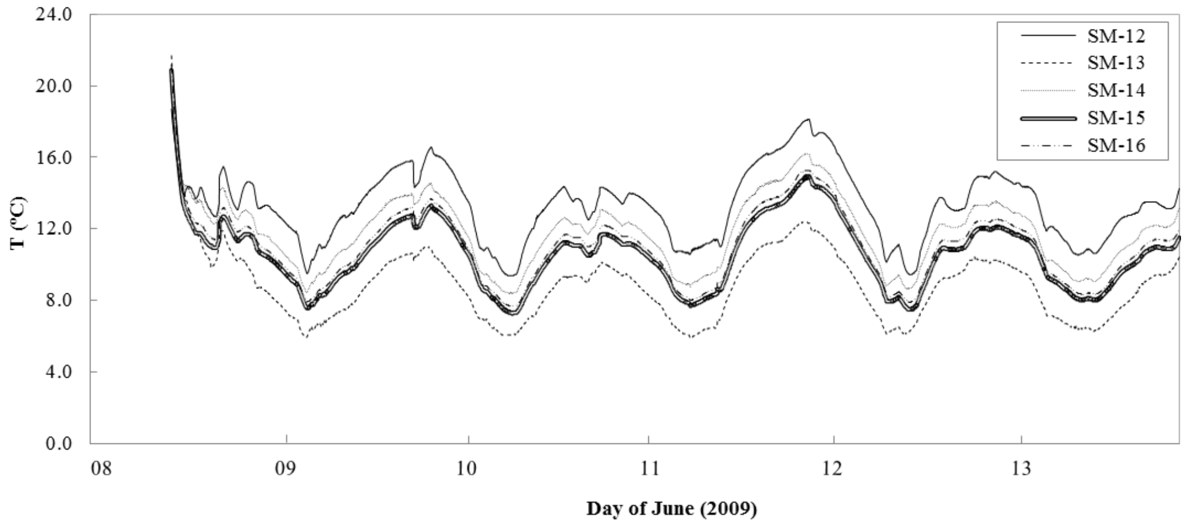

Figure 8. ISLiD Optics Unit SM temperature sensors

selected wind shield consisted of linear low-density polyethylene (LLDPE) film, 1.5-mil thick. It has a transmissivity of 0.814 in the infrared and 0.914 in the visible, which allows the electronic boxes to be practically in the same thermal conditions as without the film during the cruise.

In polar summer, the telescope is permanently facing the Sun, and the day-to-night variations which can be observed in Figs. 7 and 8 are mainly due to the change in the albedo thermal loads, dependent on the Sun elevation angle. In the plots, these maximum and minimum temperatures do not fit with noon and midnight because the time (*x*-axis) is universal time instead of local time.

4. RESULTS AND CONCLUSIONS

The measurements taken by the sensors show that, although the temperatures were not within the interval 20 ± 10ºC, indeed the maximum amplitude in the cruise phase for the PFI temperatures was 21.5ºC for the ISLiD/SUFI optics bench, and 12ºC in the case of ISLiD optical elements. The temperature amplitude of 21.5ºC for ISLiD/SUFI is a bit bigger than the thermal control system target, but in fact the scientific performance was not jeopardized for this cause. Practically all the temperatures of PFI equipment were colder than desired values, but it should be noted that, due to programmatic issues, part of the PFI was manufactured while the design of other involved parts were not frozen. An instrument, which was going to be mounted on the PFI module, finally was cancelled; therefore the distribution of the power dissipation changed.

Sunrise is planned to fly again in June 2012, and the thermal control, system will have to be revised, taking into account all the priceless information retrieved from the June 2009 flight.

5. ACKNOWLEDGEMENTS

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